Polyphagy in *Clonopsis gallica* (Charpentier): a survey of woody plant species.

Michael G. Guye, 1 route du Gat Mort, 33650 Cabanac et Villagrains, France.

Key words
Phasmida, *Clonopsis gallica*, plant acceptability, relative preference, foodplant ranking, leaves, petals, plant family, plant species, polyphagous behaviour.

Abstract
A survey of 50 woody plant species was carried out to determine the relative acceptability of the leaves (under "non-forced diet" conditions) as a potential food source for *Clonopsis gallica* (Charpentier). Twenty-five of the 29 species accepted are reported here for the first time as potential foodplants. These species belong to the following taxonomic families: Betulaceae, Cornaceae, Fagaceae, Rhamnaceae, Rosaceae, Saliceae, Tiliaceae and Ulmaceae. Under field conditions *C. gallica* appears to be most commonly found feeding on rose and bramble (Rosaceae). An examination of 18 other Rosaceae revealed that not all were accepted. Out of eight evergreen species tested only two were accepted and these were both Rosaceae. Where flower material was provided the petals were readily eaten, even in species where leaf material was avoided.

Introduction
Clonopsis gallica (Charpentier) appears to be widely distributed within France (with the exception of eastern, northern and north-eastern France) and throughout many coastal regions of The Mediterranean and North Africa (Brock, 1991; Chopard, 1951; Finot, 1890; Lelong, 1994). Observations concerning the feeding behaviour of *C. gallica* (Table 1) indicate that it is polyphagous for at least 12 plant species, though under field conditions it is most commonly found feeding on *Rosa* and *Rubus* species. However 12 out of the 18 observations cited in Table 1 provide an inadequate description of the foodplant material identified (e.g. species names have been omitted). For example, *C. gallica* was reported to feed on *Prunus* sp. (see Bullini, 1981) though this description is clearly deficient since the *Prunus* genus contains numerous species and hybrids (Davies, 1987; Stace, 1991). In addition no information is available concerning plant families or species which are not eaten by *C. gallica*. A more comprehensive survey of potential foodplants is therefore warranted in order to evaluate more fully the polyphagous behaviour of this phasmid.

The main aim of the present study was to investigate the acceptability of leaves (and in some cases flowers) of a wide range of plant species as a potential food source for *C. gallica* under captive conditions. The material provided was always tested in the presence of the standard rosaceous foodplants (i.e. rose or bramble). This allows freedom of expression of relative food preferences (i.e. "non-forced diet" conditions). A subjective ranking has been made for the acceptability of the test species relative to the standard foodplant species. Wherever possible a complete taxonomic description of the plant material used has been given (i.e. family, genus, species, and cultivar where either relevant or known), together with any further details. Some of this material was found growing within the vicinity of rose and bramble plants on which *C. gallica* was found feeding under field conditions. The handling of thorny foodplants such as rose and bramble can be awkward and such material may inflict wounds on both insect and experimenter during a moment of inattention, particularly when cleaning out rearing cages. A search for a thornless potential substitute was therefore a further aim.

Materials and methods
a) Rearing conditions
The present study was carried out in 1994 and 1995. The phasmid species used, *Clonopsis gallica* (Charpentier), has been in culture by the author since summer 1991, the present parthenogenetic stock originating from three females found on bramble and rose plants growing in the author's

garden (Villagrains, Gironde, S.W. France).

Reference	Plant species	conditions	place or region of field observation
Brock (1991)	[1]*Cytisus scoparius*	F	Algarve, S. Portugal
	[1]*Cytisus* sp.	F	
Bullini (1981)	[2]*Crataegus* sp.	F C	Mediterranean region
	[2]*Prunus* sp.	F C	
	[2]*Rosa* sp.	F C	
	[2]*Rubus* sp.	F C	
	[3]*Coriaria myrtifolia*	C	
	[2]*Potentilla* sp.	C	
	[1]*Genista* sp.	C	
	[4]*Hypericum perforatum*	C	
Gangwere & Morales Agacino (1973)	[5]*Daphne gnidium*	F	Javea, S.E. Spain
Garnier, Langlois & Lelong (1994)	*Rosa* sp.	C	Escalquens (Haute-Garonne, S.W. France)
	[2]*Prunus spinosa*	F	
Guye (1995)	*Rosa* sp.	F	Villagrains (Gironde, S.W. France)
	Rubus sp.	C	
Scali & Mazzini (1981)	[6]*Pistacia lentiscus*	C	
Voy (1954)	*Rosa* sp.	F C	Montfort-en-Chalosse (Landes, S.W. France)
	Rubus sp.	C	

Table 1. Published data concerning foodplant species of *Clonopsis gallica* under field (F) and captive (C) conditions. Families of the plants are indicated by: [1]Leguminosae, [2]Rosaceae, [3]Coriariaceae, [4]Guttiferae, [5]Thymelaeaceae, [6]Anarcardaciae.

Around 200 specimens (of approximately the same developmental stage) were reared in a wooden cage measuring 60cm length x 44cm breadth x 50cm height. The front of the cage was removable and made of a 1.4 mm mesh netting to provide adequate aeration. Since *C. gallica* prefers cool conditions, i.e. 18-20°C (see Brock 1991), the rearing tank was kept in an unheated north-north-west facing room away from direct sunlight. Throughout the study day temperatures were within the range of 17-23°C (mean value of 18.7°C $\pm$ standard deviation of 1.6) and night temperatures within the range 14-20°C (mean value of 16.5°C $\pm$ standard deviation of 1.5). The threshold temperature for feeding in this species appears to be around 10°C (Guye, unpublished observation). Since the cage was in a poorly lit location artificial lighting was provided. A low-energy electronic lightbulb (9 watts, Globolux 110 - Orion, Austria) was programmed to give 16 hours of light (500-600 lumens) for every 24 hour period. Reasons for choosing this type of lightbulb were two-fold. First heating effects are minimal: the surface of the bulb is cool enough for an insect to walk on it without injury. Second, a significant financial saving is made relative to an incandescent bulb of similar light output due to the considerably lower power consumption

and longer operational life.

Branches of the standard foodplant, bramble (*Rubus fruticosus* agg.), possessing both young mature (recently fully-expanded) and immature (expanding) leaves were replenished each week. These were placed in a jar of water, the cut-end of the stems passing through holes drilled in the plastic screw-cap cover. In general an attempt was made to harvest fresh material early in the morning, while the vegetation was still covered in dew. Since the water content of leaf tissue is near to it s maximum daily value at around dawn, due to nocturnal rehydration (Kramer, 1983), plant material harvested around this time was considered to be of better quality than that harvested later during the day. Alternatively plant material harvested later in the day was rehydrated by immersion in a bowl of tap water for one to two hours. Water droplets on plant material were allowed to evaporate before the material was placed in the rearing cage. Neither *C. gallica* nor its foodplant were sprayed with water since this species appears to prefer a fairly dry environment.

b) Feeding trials

The comprehensive field guide of Stace (1991) was used to check the identity and taxonomy of the plant material used. Plant hybrids which have attained a geographic distribution that is no longer tied to that of their parents (i.e., those that occur at least sometimes in the absence of both parents) are treated exactly like species, and are indicated in Table 2 with the multiplication sign inserted between the generic name and the specific epithet, i.e. *Fragaria* x *ananassa* and *Spiraea* x *vanhouttei* (Stace, 1991).

Feeding trials were carried out on second to fifth (adult) instars of *C. gallica*. The standard foodplant material was supplemented once each week with other plant species (see Table 2). The exception to this was branches of immature leaves of *Quercus robur* which were replaced twice a week as the quality of this material declined visibly within three to four days of harvesting (i.e. the leaves blackened). All material was harvested from plants growing outdoors with the exception of *Fragaria* x *ananassa* which was greenhouse-grown.

The main aim of this investigation was to determine potential foodplant acceptability for *C. gallica* under conditions of foodplant choice rather than under "forced-diet" conditions: the latter would be the case if alternative species were given in the absence of the standard foodplants. A relative ranking for the acceptability of each species as a foodplant was then given, using bramble as a reference. The ranking was as follows: not eaten (-), briefly sampled on contact but no further feeding (+), sampled and some subsequent feeding (++), and prolonged feeding (+++). The ranking used was a visual estimation of the leaf surface area consumed during a single feeding period (it did not refer to the total amount of leaf material eaten within a week).

Results and discussion

The leaves of 25 different plant species are reported here for the first time as potential food sources for *C. gallica* under captive conditions. These species were eaten to varying degrees and were as follows: *Alnus glutinosa*, *Betula pendula*, *Corylus avellana*, *Castanea sativa*, *Cornus sanguinea*, *Quercus petraea*, *Q. robur*, *Q. rubra*, *Frangula alnus*, *Chaenomeles japonicum*, *Cotoneaster buxifolius*, *Crataegus monogyna*, *Fragaria* x *ananassa*, *Prunus armeniaca*, *P. domestica*, *P. insititia*, *P. persica*, *P. persica* x *amygdalus*, *Pyracantha coccinea*, *Pyrus communis*, *Rubus idaeus*, *Salix aurita*, *S. cinerea*, *Tilia cordata* and *Ulmus carpinifolia* (Table 2). Where flower material was offered (*Cytisus scoparius*, *Ulex europaeus*, *Malus domestica* and *Rosa* sp.) the petals were readily eaten. It is interesting to note that in two of these species (*U. europaeus* and *M. domestica*) leaf material was not eaten.

Out of 18 Rosaceae, in addition to rose and bramble, five species were not eaten (i.e. *Cotoneaster lacteus*, *Cydonia oblonga*, *M. domestica*, *Prunus avium* and *Spiraea* x *vanhouttei*). More than one species was examined for the Caprifoliaceae, Grossulariaceae and Oleaceae. For each of these three families leaves were not eaten though it remains to be determined if this is typical for these families. Only one out of three Leguminosae was accepted.

The ranking method used to indicate relative acceptability (i.e. surface area of leaf tissue consumed by a phasmid in a single feeding period) is meant only as a rough guide. A more precise study should include a calculation of the weight of material consumed since more surface area would be expected to be eaten for a plant with thin leaves than for one with thick leaves, assuming that both species are equally palatable. In many cases it appeared that the plant species being tested was consumed only by a small proportion of the phasmid population used (i.e. in some cases only two or three leaves on a branch were eaten, though these leaves may have received a ranking of "+++"). Therefore the ranking given was limited to the feeding behaviour at the level of an individual polyphagous phasmid: it did not quantify the extent of polyphagy at population level (i.e. it did not define the percentage of individuals in a given population showing polyphagy).

One of the aims of the present work was to identify potential foodplant species that may be used as a substitute for rose or bramble. The ideal candidate would be a non-thorny evergreen. Evergreen material is particularly useful during late winter and early spring when the quality of bramble growing outdoors may be poor. Additionally, in the absence of easily available outdoor material, the alternative species should be easy to propagate (e.g. from cuttings or suckers) and grow relatively rapidly. Several non-thorny species are eaten, though *Cotoneaster buxifolius* represents the only non-thorny evergreen species (Table 2). However this species is slow-growing. Assuming that a winter food source is not required many of the above could be used though *Rubus idaeus* probably represents the best choice since it is the most closely related to bramble.

Quercus robur and *Castanea sativa* appear at opposite ends of a spectrum regarding the number of insect species found associated with them, i.e. 284 versus five insect species respectively (Anon., 1980). Though association does not necessarily imply herbivory (i.e. some of these insects will be predatory), it may be assumed that these figures are likely nevertheless to reflect an extreme difference in the number of insects feeding on these species. It was therefore a surprise to find *C. sativa* to be so readily accepted by *C. gallica*.

Differences in the acceptability of the different *Quercus* spp. examined may be due to differences in the surface characteristics of the leaves, particularly with regard to hairiness. For example *Q. robur* and *Q. rubra* were readily accepted and these species have glabrous leaf surfaces. However, *Q. petraea* (poorly accepted) and *Q. toza* (not eaten) have pubescent leaf surfaces. Similarly the avoidance of both *Cydonia oblonga* and *Cotoneaster lacteus* may be due to the pubescent to tomentose nature of the lower leaf surfaces.

The results of the present study, together with previous work, clearly demonstrate that *C. gallica* is a highly polyphagous species, i.e. a total of 36 species are accepted to varying degrees (Tables 1 and 2). However the percentage of individuals showing polyphagous behaviour within a given population needs to be determined. In addition, it remains to be determined whether alternative species may provide a suitable food source to rose or bramble. The most important criterion for such a food source is that it allows *C. gallica* to complete its life-cycle and reproduce. Alternative food material, though apparently non-essential, may nevertheless play a role as a dietary supplement in providing a "balanced nutrition". Such questions are under investigation by the present author.

Table 2. Feeding behaviour of *Clonopsis gallica* in captivity on a range of woody plant species (see following page for explanation).

Plant family	Taxonomic name (common name)	Acceptability of leaves	Further details
Aceraceae	*Acer negundo* (ashleaf maple)	-	D
Araliaceae	*Hedera helix* (ivy)	-	E 1
Berberidaceae	*Mahonia aquifolium* (Oregon grape)	-	E 1
Betulaceae	*Alnus glutinosa* (alder)	+++	D
Betulaceae	*Betula pendula* (silver birch)	+++	D
Betulaceae	*Corylus avellana* (hazel)	+++	D 1
Caprifoliaceae	*Lonicera periclymenum* (honeysuckle)	-	D 1
Caprifoliaceae	*Viburnum tinus* (viburnum)	-	D 1
Caprifoliaceae	*Sambucus nigra* (elder)	-	D 1
Celastraceae	*Euonymus europaeus* (spindle tree)	-	D 1
Cornaceae	*Cornus sanguinea* (dogwood)	++	D
Fagaceae	*Castanea sativa* (sweet chestnut)	+++	D 2
Fagaceae	*Quercus petraea* (sessile oak)	+/++	D 2
Fagaceae	*Q. robur* (pedunculate oak)	++/+++	D 1 2
Fagaceae	*Q. rubra* (red oak)	+++	D 3
Fagaceae	*Q. toza* ("tauzin" oak)	-	D 3 4
Grossulariaceae	*Ribes rubrum* (red currant)	-	D
Grossulariaceae	*Escallonia macrantha* (escallonia)	-	E
Juglandaceae	*Juglans regia* (walnut)	-	D
Leguminosae	*Cytisus scoparius* (broom)	++	D 5
Leguminosae	*Robinia pseudoacacia* (false-acacia)	-	D T 1
Leguminosae	*Ulex europaeus* (gorze)	-	D T 5
Oleaceae	*Ligustrum vulgare* (privet)	-	E
Oleaceae	*Syringa vulgaris* (lilac)	-	D 1
Oleaceae	*Fraxinus excelsior* (ash)	-	D 2
Rhamnaceae	*Frangula alnus* (alder buckthorn)	++/+++	D
Rosaceae	*Chaenomeles japonicum* (ornamental quince)	++	D 1
Rosaceae	*Cotoneaster buxifolius* (box-leaved cotoneaster)	++	E
Rosaceae	*C. lacteus* (late cotoneaster)	-	E
Rosaceae	*Crataegus monogyna* (hawthorn)	++	D T
Rosaceae	*Cydonia oblonga* (quince)	-	D 6
Rosaceae	*Fragaria* x *ananassa* (garden strawberry)	+++	D 7
Rosaceae	*Malus domestica* (apple)	-	D 5
Rosaceae	*Prunus armeniaca* (apricot)	++	D 8
Rosaceae	*P. avium* (sweet cherry)	-	D 1 9
Rosaceae	*P. domestica* (plum)	++/+++	D 10
Rosaceae	*P. insititia* (French cherry plum)	++/+++	D 1 11
Rosaceae	*P. laurocerasus* (laurel)	+	E 1
Rosaceae	*P. persica* (peach)	++	D
Rosaceae	*P. persica* x *amygdalus* (peach-almond hybrid)	++	D
Rosaceae	*Pyracantha coccinea* (firethorn)	++/+++	E T
Rosaceae	*Pyrus communis* (pear)	++	D
Rosaceae	*Rosa* sp. (garden rose)	+++	D T 5
Rosaceae	*Rubus fruticosus* agg. (bramble)	+++	D/E 12
Rosaceae	*R. idaeus* (raspberry)	+++	D
Rosaceae	*Spiraea* x *vanhouttei* (Van Houtte's Spiraea)	-	D
Saliceae	*Salix aurita* (eared willow)	++	D
Saliceae	*S. cinerea* (grey willow)	++	D
Tiliaceae	*Tilia cordata* (small-leaved lime)	++	D
Ulmaceae	*Ulmus carpinifolia* (smooth-leaved elm)	++	D 1
Vitaceae	*Vitis vinifera* (grapevine)	-	D

Key to table 2.

Acceptability of leaves: This column indicates relative feeding preferences as follows: not eaten at all (-); briefly sampled on contact but no further feeding (+); sampled and some subsequent feeding (++); prolonged feeding (+++).

Further details: (D) deciduous; (E) evergreen; (D/E) intermediate between D and E; (T) possessing thorns; (1) found growing within a 10 metre radius of bramble and rose foodplants where *C. gallica* was originally found feeding; (2) only immature leaves provided; (3) only immature leaves eaten/mature leaves avoided (4) an oak species generally limited to southwestern Europe; (5) petals of flowers readily eaten; (6) cv. Champion; (7) cv. Elsanta, greenhouse-grown; (8) cv. Bergeron; (9) cv. Napoleon Bigarreau and a garden escape of unknown provenance were tested; (10) cv. Reine-Claude d'Ouillans; (11) cv. Mirabelle de Nancy; (12) [agg.] = aggregate - most taxa of the subgenus *Rubus* form an extremely complex group which is difficult to classify and so are often known collectively by this name.

Addendum

Since this article was prepared I have been informed that *C. gallica* may also be found feeding on *Prunus dulcis* (wild almond) and *Dorycnium suffruticosus* (dorycnium) under field conditions (Philippe Lelong, personal communication). Therefore *C. gallica* appears to be polyphagous for at least 38 plant species.

References

Anon. (1980) *Woodlands - a practical handbook.* British Trust for Conservation Volunteers (pubs). The Eastern Press Ltd., Reading (Berks) [Reprinted 1991].

Bullini, L. (1981) Trophic niche of Mediterranean stick-insects *Clonopsis gallica, Bacillus rossius* and *Bacillus atticus* (Cheleutoptera, Bacillidae). *Ecologia*, 263-64.

Brock, P. (1991) *Stick insects of Britain, Europe and the Mediterranean.* Fitzgerald Publishing, London.

Chopard, L. (1951) *Faune de France. Vol. 56 - Orthopteroïdes.* Paul Chevalier, Paris [6th edition].

Davies, B. (1987) *The Gardener's illustrated encyclopedia of trees and shrubs.* Penguin Books Ltd, Middlesex.

Finot, A. (1890) *Faune de France. Insectes - Orthoptères*, pp. 94-95. Fontainbleu.

Gangwere, S.K. & Morales Agacino, E. (1973) Food selection and feeding behaviour in Iberian Orthoptera. *Anales. Istituto Nacional de Investigaciones Agrarias (Spain). Serie Proteccion Vegetal*, 3: 251-337. [not seen - cited by Brock, 1991].

Garnier, G., Langlois, F. & Lelong, P. (1994) Etude in situ de la mobilité du phasme *Clonopsis gallica* (Charpentier, 1825) "première partie". *Le Monde des Phasmes*, 27-28: 3-9.

Guye, M (1995) Predation of eggs of *Clonopsis gallica* by crickets. *The Phasmid Study Group Newsletter*, 62: 9-10.

Kramer, P. (1983) *Water relations of plants.* Academic Press, (London).

Lelong, P. (1994) Cartographie des espèces Françaises. *Le Monde des Phasmes*, 25: 24-26.

Scali, V. & Mazzini, M. (1982) Interpopulation differences in egg sculpturing of the stick insect, *Clonopsis gallica* (Charp.) (Phasmatodea: Bacillidae). *International Journal of Insect Morphology and Embryology*, 11: 189-195 [not seen - cited by Brock, 1991].

Stace, S (1991) *New Flora of the British Isles.* Cambridge University Press.

Voy, A. (1954) Biologie et croissance chez le phasme femelle (*Clonopsis gallica* Charp.). *Bulletin Biologique de la France et de la Belgique*, 88: 101-129.